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Method of detecting a malfunction during a displacement of an element by means of a drive system, and device suitable for carrying out such a method

The invention relates to a method of detecting a malfunction during a displacement of an element by a drive system, in which method a processor determines a difference between a predetermined desired value and an actual value at regular intervals during the displacement of the element.

The invention further relates to a device suitable for carrying out such a method.

Such a method is known per se from EP-B1-0 365 681. A collision between machine parts driven by servomotors and an object can be detected by means of the method described therein. A processor calculates the derivative of the speed of the servomotor during a preceding period and subtracts it from the derivative of the speed of the servomotor over the present period. The absolute value of the calculated difference is taken, and this is compared by the processor with a given reference value. If the value is greater than the given reference value, this is interpreted as an indication that there is a collision.

Such a method has the disadvantage that the detection of a collision takes comparatively much time because the minimum time required for detecting the collision is equal to the length of the chosen time period, with the result that the malfunction may already have occurred at the beginning of the measured period.

The invention has for its object to provide a method wherein the time required for detecting a malfunction is comparatively short.

This object is achieved in the method according to the invention in that the processor further determines a derivative of the difference at regular intervals, said difference and its derivative both fluctuating around an equilibrium value, whereupon only the values at one side of the equilibrium value of the both the difference and the derivative are taken, the values of the difference are multiplied by the value of the derivative, the outcome of the multiplication is compared with a reference value by the processor, and a malfunction in the

displacement of the element is detected if the outcome of the multiplication is higher than the reference value.

The multiplication of the value of the derivative of the difference by the value of the difference at a single side of the equilibrium value generates a curve in time which has a comparatively steeper slope (also denoted comparatively great directional coefficient) in the case of a malfunction than the curve of the value of the derivative and/or the curve of the difference value. As a result, the curve will rise comparatively quickly in the case of a malfunction, so that the reference value is reached comparatively quickly, and a malfunction can be ascertained and detected.

An embodiment of the method according to the invention is characterized in that the chosen side of the equilibrium value is dependent on the direction in which the element is displaced.

If the element has a certain speed in a certain direction, the speed in said direction will drop below the desired value the moment a collision occurs. This information is relevant for detecting a collision. The information that the speed of the element is higher than the desired value is of no importance in such a case and may accordingly be set for zero.

Another embodiment of the method according to the invention is characterized in that the signals of the derivative are filtered.

An advantage of this is that exclusively those signals remain owing to the signal filtering which are relevant for making a malfunction detection possible.

A further embodiment of the method according to the invention is characterized in that the predetermined desired value represents the desired position of the displaceable element, while the actual value represents the actual position of the element.

An advantage of such a method is that the element can be accurately displaced into a desired position, while a malfunction during the displacement, such as a collision, is detected comparatively quickly.

It is a further object of the invention to provide a device by means of which a malfunction in a drive system for the displacement of an element can be detected comparatively quickly.

This object is achieved in the device according to the invention in that the device is provided with an element that is displaceable by means of a drive system and with a processor provided with means for comparing a desired value with an actual value, means for determining a derivative, means for determining values lying at one side of an equilibrium

value, multiplication means, and means for comparing the outcome of a multiplication with a reference value.

A malfunction, such as a collision, can be detected comparatively quickly by means of such a device, as was described further above.

The invention will be explained in more detail below with reference to the accompanying drawings, in which:

Fig. 1 shows a component placement device;

Fig. 2 shows a control circuit of the device shown in Fig. 1, in which a feedback between the processor and the drive system is shown;

Fig. 3 is a graph representing a difference between a desired value and an actual value in time, and a derivative thereof;

Fig. 4 is a graph showing curves representing the difference and the derivative of the difference after the positive part has been set for zero; and

Fig. 5 shows the graph of Fig. 4, now containing a further curve corresponding to the multiplication of the curves shown in Fig. 4.

Corresponding components have been given the same reference numerals in the Figures.

Fig. 1 shows a component placement device 1 which is provided with a frame 2. Rails 3 are situated on the frame 2 at both sides. A guide 4 extends transversely to the rails 3 and is displaceable over the rails 3 by means of a drive system (not shown) in and opposite to the direction indicated by arrow P1. An arm 5 is provided on the guide 4, which arm is displaceable by means of a drive system over the guide 4 in and opposite to the direction indicated by arrow P2. The direction of arrow P2 is perpendicular to the direction of arrow P1. An imaging device 6 and a placement device 7 are fastened to the arm 5.

A transport device 8, by means of which substrates 9 are displaceable in the direction indicated by arrow P2, is present below the arm 5. Each substrate 9 is provided with at least one reference element 10. The component placement machine 1 is further provided with a component feeder device 11 from which components can be taken by the placement device 7. A further imaging device 12 is located on the frame 2.

Fig. 2 shows a control circuit 13 of a processor of a component placement device 1, diagrammatically showing a controller 14 by means of which a drive system 15 of the arm is controlled. The arm 5 will always be controlled such that the placement device 7 is displaced into a desired position. This desired position is applied to a difference determinator 16 via input element 17. The actual position of the placement device 7 realized by the controller 14 and the drive system 15 will also be applied to this difference determinator 16.

The control circuit 16 discussed thus far is known per se and will accordingly not be described in any more detail.

Fig. 3 shows a graph with two curves, curve A representing the difference between the desired position and the actual position of the placement device 7 in time t, while curve B is the derivative of curve A in time. As is apparent from the graph, the curves A and B vary around an equilibrium value 0. It is visible in the graph that a malfunction occurs in the curve A at a moment t_v, such that the difference between the desired position and the actual position assumes a considerable negative value. Such a situation may arise, for example, if the placement device 7 is displaced in the direction indicated by arrow P1, which direction indicated by arrow P1 corresponds to the negative X-direction. The curve B, being the derivative of curve A, first shows a steep drop, whereupon it assumes a constant negative value.

The malfunction may be caused, for example, by the fact that the placement device 7 during its displacement hits against a component already provided on the substrate 9, with a collision as a result.

The actual position of the placement device 7 will never be beyond the desired position in the direction indicated by arrow P1 in the case of a collision during the displacement of the placement device 7 in the direction of arrow P1. This means that the part of the curve for which the difference between the desired position and the actual position is positive may be disregarded. Accordingly, this value is set for zero in the controller 14 in accordance with the method according to the invention.

Fig. 4 shows the curves A and B of Fig. 3, with the parts of the curves A and B situated above the equilibrium value 0 being reset to 0.

Fig. 5 shows the curves A and B of Fig. 4 as well as a curve C. The curve C is the multiplication of the curves A and B. The curve C occasionally assumes positive values with a maximum amplitude R which is considerably smaller than the amplitudes of the curves A and B over the time period from t_0 to t_v. This amplitude over the indicated time period t_0-t_v may serve as a reference value R for detecting a normal displacement.

From the moment t_v onwards, i.e. the moment the collision takes place, the curve C rises with a very steep gradient. As is visible in Fig. 5, the accompanying value of curve C will be considerably higher than the amplitude of curve C in the time period t_0-t_v a very short time after t_v already. The moment the reference value R is exceeded, which is the case comparatively soon after moment t_v already, as described above, this can and will be regarded as a signal that a collision has taken place. The arm 5 should now be stopped by means of the processor or be displaced in a direction opposed to that of arrow P1 so as to avoid damage to the placement device 7 and/or the substrate 9.

It is also possible to determine a higher-order derivative instead of the derivative of curve B. A higher-order derivative is more accurate, but also increases the required calculation time. Depending on the desired application, a compromise between accuracy and the desired calculation time will have to be made.

The controller 14 may carry out a filtering function during determining of the derivative, if so desired, so as to remove noise and other undesirable effects from the measured curve.

It is also possible to supply a desired and actual speed, force, or temperature to the difference determinator 16 instead of the desired and actual positions.

It will be obvious that the desired and actual positions of the placement device 7 processed in the control circuit 13 may relate to the X- as well as to the Y- and Z-directions.

It is also possible to apply the method according to the invention to a rotary instead of a translatory displacement.

The graphs of Figs. 3 to 5 merely show an example. In practice, the difference between the actual value and the desired value will fluctuate much more irregularly. In addition, the transition caused by a disturbance of the derivative is usually not a stepped one, but has a comparatively great directional coefficient.

It is also possible to take a reference value of, for example, 2R instead of the reference value R.

It is also possible to multiply the difference by both the first and the second derivative, so that a malfunction can be detected even more quickly.